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WEAR RESISTANT STEEL  
[Taimamoko]

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## Specifications

### 1. Title of the Invention

Wear resistant steel

### 2. Claims

- (1) Wear resistant steel comprising 0.35~0.45% C, 0.60~1.50% Si, less than 1.80% Mn, 2.50~4.50% Cr and 0.20~1.00% Mo by weight, with the balance Fe and unavoidable impurities.
- (2) Wear resistant steel comprising 0.35~0.45% C, 0.60~1.50% Si, less than 1.80% Mn, 2.50~4.50% Cr and 0.20~1.00% Mo by weight, as well as one, two or more types of 0.01~0.50% V, 0.01~0.10% Nb and 0.01~0.50% W, with the balance Fe and unavoidable impurities.
- (3) Wear resistant steel comprising 0.35~0.45% C, 0.60~1.50% Si, less than 1.80% Mn, 2.50~4.50% Cr and 0.20~1.00% Mo by weight, as well as both 0.01~0.10% Ti and 0.0005~0.0030% B, with the balance Fe and unavoidable impurities.
- (4) Wear resistant steel comprising 0.35~0.45% C, 0.60~1.50% Si, less than 1.80% Mn, 2.50~4.50% Cr and 0.20~1.00% Mo by weight, as well as one, two or more types of 0.01~0.50% V, 0.01~0.10% Nb and 0.01~0.50% W, both 0.01~0.10% Ti and 0.0005~0.0030% B with the balance Fe and unavoidable impurities.

### 3. Detailed Explanation of the Invention

#### [Industrial Field of the Invention]

This invention relates to a wear resistant steel, in particular a wear resistant steel that has excellent durability as a steel material for all types of parts used in construction equipment.

## [Technical Background]

Presently, examples of parts used in construction equipment include track shoes, track links, track bushings, sprockets, track rollers, cutting edges, end bits, ripper shanks, ripper points and chisels that are made with wear resistant steel. Representative examples include manganese steel (SMn steel) and chromium manganese steel (SMnC steel) for G4106 equipment construction; chromium molybdenum steel (SCM steel) for G4105; chromium steel (SCr steel) for G4104; nickel chromium molybdenum steel (SNCM steel) for G4103; and nickel chromium steel (SNC steel) for G4102 for JIS standards. In particular, SCM steel 440 with the following composition (0.38~0.43% C, 0.15~0.35% Si, 0.60~0.85% Mn, a maximum of 0.030% P, a maximum of 0.030% S, 0.90~1.20% Cr, 0.15~0.30% Mo and the balance of Fe) is widely used.

Properties required for all of the aforementioned parts include (1) good machinability; (2) sufficient ability to harden when quenching; (3) excellent wear resistance; (4) superior durability and resistance to breaking; (5) good fatigue resistance; (6) good repairability with mechanical processing and gas welding on worn areas; and (7) excellent economical feasibility. These properties required for all of these parts for construction equipment are quite disparate. As a result, the following problems exist when evaluating steel used at the present time, such as SCM440 mentioned above.

### (1) Insufficient Quenching

Even with water quenching, complete hardening to the core only occurs up to about 50mm in diameter, so parts larger than this are not hardened to the core.

## (2) Insufficient Wear Resistance

With existing steel related to (1) above, the depth to which large parts are hardened is insufficient so if the surface of the hardened layer is temporarily subject to abrasion, the interior begins to wear rapidly and shortens the life of the part. If the temperature rises (400-500°C) due to wear from dirt, sand, concrete and rocks, the hardened layer softens during use and the wear resistance deteriorates.

### [Summary of the Invention]

The present invention solves the problems present in existing steel and is a product that is capable of improving the wear resistance by modifying the amounts of each element in the alloy. The amounts of C, Si, Mn, Cr, Mo as well as V, Nb, W, Ti, B as required are modified to significantly improve the quenching ability, heat resistance and wear resistance. This produces a steel product that can be used for general purposes as parts for all types of wear resistance. The product contains 0.35~0.45% C, 0.60~1.50% Si, less than 1.80% Mn, 2.50~4.50% Cr and 0.20~1.00% Mo by weight, as well as one, two or more types of 0.01~0.50% V, 0.01~0.10% Nb and 0.01~0.50% W, and (or) both 0.01~0.10% Ti and 0.0005~0.0030% B with the balance Fe and unavoidable impurities.

### [Detailed Description]

As indicated above, the present invention is a product targeting development of steel with excellent wear resistance applicable to all types of parts used in construction equipment. After quenching and annealing, the product should have a hardness of Hv600 max at a normal temperature and Hv350 min at a high temperature. Here, the idea of

controlling the normal hardness to less than Hv600 is to maintain resistance to breaking by preventing a deterioration in durability.

Also, the reason for controlling the high temperature hardness to greater than Hv350 is to assume elevating the part to a maximum temperature of 500°C during use, which will impart wear resistance by preventing softening in this temperature range.

Next is a description of the reasons for the ranges for the elements for the steel in the present invention.

C: 0.35~0.45%:

C is an element necessary for obtaining a specific hardness with the martensite structure and thus requires an addition of at least 0.35%. More than 0.35% is necessary to improve the wear resistance by forming a carbide alloy in the steel of other alloy elements (Cr, Mo, V, Nb, W, etc). On the other hand, if the amount added exceeds 0.45%, the durability will dramatically deteriorate and after quenching, the residual austenite amount will increase, which causes a deterioration in the wear resistance so the upper limit has been set at 0.45%.

Si: 0.60~1.50% Si:

Approximately 0.25% of Si is added for deacidification of standard steel but at this level, there is no improvement in wear resistance. Adding more than 0.60% improves the wear resistance. However, adding more than 1.50% adversely impacts durability so the upper limit is 1.50%.

Mn: less than 1.80%:

Approximately 0.60% of Mn is added for deacidification and desulfurization of steel but this amount in the present invention can be determined according to the objective of modifying the quenching

ability for the size of the part. However, adding more than 1.80% results in steel segregation, adversely impacts durability and causes hydrogen damage so the upper limit is 1.80%.

Cr: 2.50~4.50%:

Cr is a very important alloy element in the present invention and the amount added plays a huge part in wear resistance. Sufficient quenching will not be obtained with less than 2.50% added and if the parts are large, hardening will not take place to the core. Additionally, heating during quenching (normal temperature 850~950°C) results in complete solid solution of the Cr carbide in the steel, which does not result in improved wear resistance. On the other hand, if the amount added exceeds 4.50%, the effect of improved wear resistance becomes saturated and durability is negatively impacted so the upper limit is 4.50%.

Mo: 0.20~1.00%:

Mo enhances the hardness without causing a deterioration in durability so is an element very effective at improving the wear resistance. To achieve this result, at least 0.20% should be added. On the other hand, if the amount added exceeds 1.00%, the effect of improved wear resistance becomes saturated, which is not economically feasible so the upper limit is 1.00%.

P, S:

The amount of P and S is not specified in the present invention. Since P and S do not impact wear resistance at all, they have little relationship to this property in the present invention but in general, there is less than 0.030% P and less than 0.035% S.

V, Nb, W:

One, two or more types of V, Nb and W are added as necessary. These elements form carbide in any steel and have the effect of improving wear resistance. To demonstrate this effect, it is necessary to add at least 0.01% of V, Nb or W. On the other hand, if more than 0.50% V is added, the durability will deteriorate so the upper limit is 0.50%. For the same reasons, the upper limits of Nb and W are 0.10% and 0.50%, respectively.

Ti, B:

Ti and B are both well known for their effects of enhancing the quenching ability of steel when used together. Quenching is improved in the present invention by adding Ti and B as necessary. Addition of Ti and B in the present invention is designed not only to improve the quenching ability but also to improve the wear resistance. To adequately achieve this effect, it is necessary to add at least 0.01% of Ti and at least 0.0005 of B. On the other hand, if more than 0.1% Ti is added, the durability will deteriorate so the upper limit is 0.10%. Likewise, if the amount of B added exceeds 0.0030%, the effect becomes saturated so the upper limit is 0.0030%.

The present invention contains the range of elements given above and if these are subject to thermal treatment, the steel in the present invention will not differ from that with standard quenching and tempering, given oil quenching after heating to 850~950°C and tempering in a range anywhere between 200~400°C. At that point, the tempering temperature can be selected so the hardness after thermal treatment is less than Hv600.

Next is a description of the embodiments for the present invention.

## Embodiment 1

Steel was produced using a standard process as shown in Table 1 as follows and rods 100mmΦ were rolled. The rolls were cut into 1000mm<sup>l</sup> lengths and were subject to thermal treatment of 900°Cx2hr heating-oil quenching-300°Cx2hr heating-air cooling. Measurements on cutting hardness at normal temperature and measurements on the hardness at a high temperature of 500°C were taken and Charpy impact tests (JIS No.3, 2mm-U-notch, 100mmΦ surface sections) were conducted. Wear tests were performed using a rotating wear tester and the amount of wear within a prescribed period of time was compared with SCM440 to determine the wear resistance index. These results are shown in Table 1.

### Key for Table:

\* shows amounts including elements that do not satisfy the conditions for the present invention

As clearly shown in Table 1 above, steel A-K comprised of elements fulfilling the conditions required of the present invention all have hardness at normal temperatures that are Hv560~600 at the surface and nearly the same hardness at the core. Additionally, the hardness at 500°C was greater than Hv350 and the wear resistance index of 3.8~5.3 was an extremely high index. The Charpy absorption energy demonstrated excellent values that were not obtained by the current steel SCM440. On the other hand, steel L~X that did not fulfill the conditions required of the present invention either had lower wear resistance compared to existing steel and there was a significant deterioration in durability, so a certain level of performance was not achieved.

Therefore, by modifying the elements in the steel for the present invention, the wear resistance can be dramatically improved, which makes it applicable for a wide variety of applications.